Ecole doctorale SMAER

Sciences **M**écaniques, **A**coustique, **E**lectronique, **R**obotique

Thesis subject 2018

Laboratory : : Institut des Systèmes Intelligents et de Robotique (ISIR)

University: Sorbonne Université

Title of the thesis: Collaborative control design strategies for robotic systems at small scales

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Collaborations within the thesis: NO

Program affiliation: /

Cotutelle: NO

University : /

This subject can be published on the doctoral school's web site: Yes

Thesis's summary (abstract):

Micro-technologies have enabled several technological breakthroughs in electronics and mechanics thanks to the development of the so-called microsystems. For a widespread development and use of microsystems, flexible and accurate robots able to do manipulation, characterization and assembly tasks at the micro-scale (1µm-1mm) are required. Actual robots are flexible and accurate but they are clearly not enough smart for micro-scale purpose, and miniaturization is now limited by human operator's dexterity and constancy. Collaborative robotics is the key to merge the best capabilities of robot and human in order to pass through the miniaturization limits and to get a productivity improvement. Collaborative robotics requires a high level switching control scheme. The aim of the thesis is the development of new control strategies on high precision robotic systems taking into account the human operator and multiple sensor signals (force, position and velocity) in the control loop. The challenge is to design and to build a set of control schemes with various levels of interactions with the operator. Different control methods may be used in parallel during a single elementary task. The robotic systems along with the proposed control strategies will be tested on concrete cases related to micro/nano-manipulation and materials characterization.

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The development of robotic systems able to perform manipulation and characterization tasks at the micro- scale (1μm-1mm) has been a dominant research topic for many years [1]. Achieving efficient and safe robotic tasks at such scales in an automated or a teleoperated way is one of the main challenges. Several robotic systems with a high resolution, precision and flexibility are now available but they are not yet smart enough to deal with complex tasks. For instance, in watch industry, the assembly of micro-mechanical components into a watch is often done by a human operator, which is able to adapt its operating mode when dealing with unpredictable situations. However, the human has not the required capabilities to deal with the physics at the small scales such as sensing forces at the micro-Newton and positioning the manipulation tool with a micrometer resolution. Micro-robotic systems are able to deal with such physical constraints but they are not able to make smart decisions. Collaborative robotics [2][3] is a key technology to improve the productivity of robotic tasks at the micro-scales. It merges the best capabilities of the human operator and the micro-robot to deal with complexes manipulation and characterization tasks on micro- components and nanomaterials.

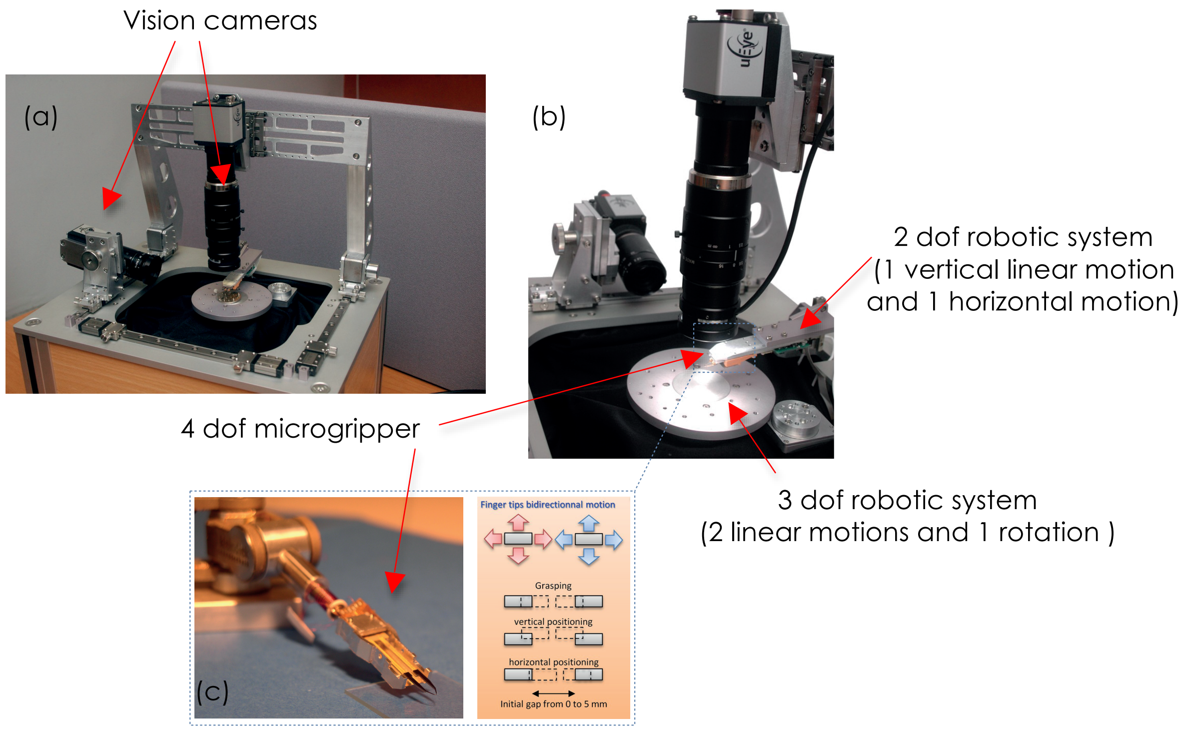

Fig.1 Chronogrip: robotic system dedicated to collaborative tasks at the micrometer scale

The project is first devoted to the design and the control collaborative robotic platforms dedicated to materials characterization and manipulation tasks at the micrometer scale. These platforms will be used as a benchmark to test, study and validate several issues related to collaborative micro/nano-robotics

The control algorithms and strategies can be thereafter applied in concrete cases using two available micro/nano-robotic systems, namely the Chronogrip (Fig.1) which is dedicated to micro manipulation and assembly tasks and the SmarPod operating inside a Scanning Electron Microscope for nanomaterials manipulation and characterization.

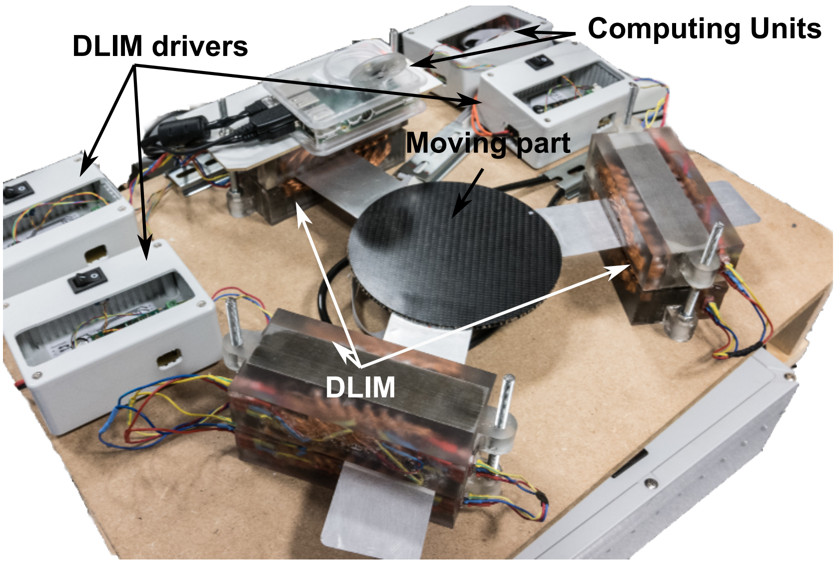

Fig.2 Haptic interface with an actuation based on linear induction motors.

The Chronogrip is composed of a microgripper with 4 DOF force sensing capability, a multi-dof high precision robotic system (a 2 dof linear robotic structure and a 3 dof robotic structure with 2 linear motions and 1 rotation) and a vision camera that includes a top view camera and a side view camera. The SmarPod is composed of a 3 DOF serial structure and a 6 DOF parallel structure. The end effector can be an atomic force microscope type cantilever. The vision is provided by the Scanning Electron Microscope. Both the Chronogrip and the SmarPod are coupled with a haptic interface such as that of Fig.2 to allow the human operator to generate a trajectory for the robotic system and to sense the interaction forces between the end effector and the environment.

The aim of the thesis is the development of new control strategies on the high precision robotic systems taking into account the human operator and multiple sensor signals (force, position and velocity) in the control loop. The challenge is to design and to build a set of control schemes with various levels of interactions with the operator (Fig.3). Two main control levels can be considered: a high level control and a low level control. In the first one, the robot is controlled considering a direct interaction with the human operator through the haptic interface, it is a teleoperated mode. The output feedback signals are the force sensed by the gripper, the position and the velocity of the robotic system and the vision camera. In the second control level, the robotic system and the end effector are controlled in an automated mode, i.e. without a direct interaction with the human operator. The global control scheme must deal with several switches to manage the operating modes of the system and to deal with priority purposes depending of the working situations.

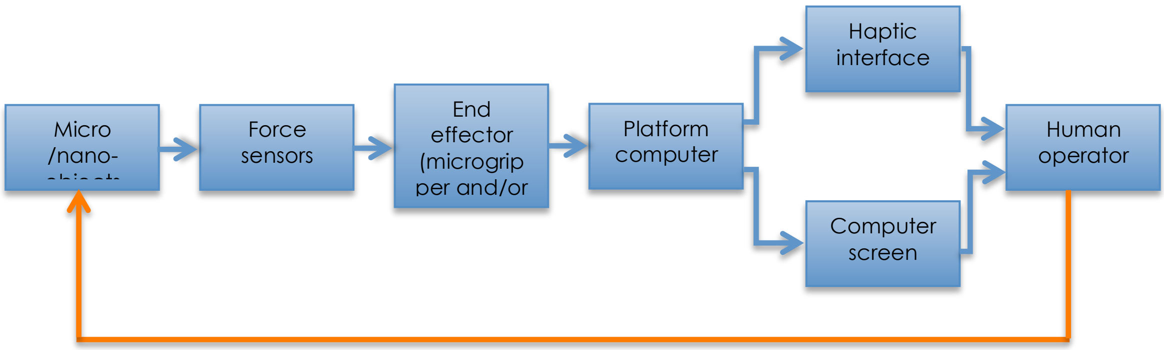

Fig.3 Control feedback scheme for the collaborative robotics

All robotic systems are composed of piezoelectric stick-slip type actuators [4][5]. Each actuator integrates an optical encoder for the measurement of the position and the velocity. The measurement resolution of the displacement is 5 nm. The actuators are able to work in a coarse positioning mode and in a fine positioning mode.

For each control level, robust control strategies must be defined for position trajectory control, velocity control and force control. The control methods can be based on the robust control theory (H_∞ based LMI control, LPV control, gain scheduling control, etc.). Hybrid, force/position and position/velocity control schemes must also be studied.

The robotic systems along with the proposed control strategies will be tested on concrete industrial cases.

The thesis must include three main contributions:

- Low-level robust control methods for multi dof robotic structures: position control, velocity control, force control, hybrid position/velocity control and hybrid force/position control.

- High-level control methods taking into account sensor signals from the microgripper, the robotic structure and the haptic interface.

- Experimental demonstrations of robust collaborative tasks for industrial assembly cases.

The expected candidate must have a multidisciplinary profile with specific skills on, mechatronics, robotics and automatic control.

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[3] Hayes B. and Scassellati B. (2014) "Online Development of Assistive Robot Behaviors for Collaborative Manipulation and Human-Robot Teamwork", Machine Learning for Interactive Systems in AAAI-14 Workshop proceedings.

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